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Method for Identifying Tire Characteristics

The present invention relates to a method for identifying tire characteristics in an electronic control unit for motor vehicles.

The method of the invention allows detecting whether new tires are mounted on the vehicle.

New tires can exhibit a constant growth of the dynamic rolling circumference until 1.0 % of the rolling circumference, in particular when they are operated for the first time at high driving speeds. It has shown that the circumferential growth commences above a defined speed and lasts for a defined time. After this time the circumference does not continue growing, the growth of the new tire is completed. Further growth will only occur upon further increase of the speed.

Especially in a per se known method of tire pressure loss detection on the basis of wheel speed data alone (e.g. Deflation Detection System, DDS, Continental Teves AG & Co. oHG, Frankfurt, EP-A 0 983 154) it is of great significance for the accuracy of the detection to precisely know effects that relate to the dynamic rolling circumference. Therefore, the method of the invention is preferably implemented in a tire pressure detection method of this type as known from the art. Initially, the DDS algorithm collects driving data on the basis of the wheel speed information and calculates from this data a reference value (hereinbelow referred to as Ref)

according to the per se known principle. Cleared from disturbances, the time variation Ref(t) represents in a particularly sensitive way deviations of the dynamic wheel circumference conditions. To begin with, the normal condition is learned after the new start (Reset) of the algorithm. The learning phase is terminated and a learned value produced when enough rotational speed values have been evaluated for the statistic evaluation. A comparison phase starts thereafter during which the actual detection of a pressure loss occurs. Current values of Ref are collected and averaged in the comparison phase. When a sufficient number of appropriate values have been collected, the averaged quantity is compared to the learned value for the pressure loss detection. When the tires are newly inflated or exchanged in the detection phase, this fact must be reported to the system by hand. However, the provision of detection devices is also possible which signal a corresponding change in the tires (DDS-Reset).

The method is preferably implemented as an algorithm in a vehicle computer to which is sent, through corresponding inputs, information of the ABS wheel speed sensors. In a particularly favorable manner, the algorithm is implemented in a microprocessor-controlled brake control unit that is already connected to the wheel speed sensors. Said control unit is especially a control unit for conventional hydraulic brake systems or for up-to-date 'brake-by-wire' brake systems such as the electrohydraulic brake (EHB) or the electromechanical brake (EMB).

According to a preferred embodiment of the invention, learned values are produced separately for predetermined speed ranges in the DDS algorithm. It is this way possible to detect speed-responsive effects of the tires. The speed-responsive

production of learned values is preferably effected in addition to the per se known production of learned values.

The method of the invention can be implemented in an especially simple manner when the observed tire growth does not occur at all four wheels at the same time. To determine the wheel at which tire growth occurs, it is preferred to evaluate several reference values that have been determined in different ways. Deviations will be encountered in the reference values determined e.g. sidewise, crosswise (diagonally) or axlewise, and the joint evaluation of the deviations permits determining the wheel position where tire growth occurred.

Further preferred embodiments can be taken from the sub claims and the following description of two embodiments by way of Figures.

In the drawings,

Figure 1 shows an algorithm for tire pressure loss detection with a detection of new tires.

Figure 2 shows diagrams representing the time variation of the vehicle speed.

Figure 3 is a detail view of an algorithm for tire pressure loss detection with new tire detection.

Figure 4 is a detail view of an algorithm for the detection of tire growth.

Figure 5 is a detail view of further diagrams for illustrating the detection of tire growth.

Figure 6 shows the schematic mode of operation of the detection of new tires.

According to a first embodiment, it is first indicated to the system in step 101, Figure 1, e.g. by way of a reset tip switch or an automatic detection device, that pressure in the tires was changed manually (e.g. pumping up of one or more tires or mounting of tires). Now, it must be checked whether new tires have been mounted in addition. To this end, the new tire detection function is activated in step 102 after pressing the reset tip switch. When new tire growth is detected in step 103, the pressure loss detection algorithm is deactivated during this time in step 104. The DDS algorithm is activated again after termination of the growth of new tires.

Figure 2a) exhibits the detection by way of four tires where the new tire growth is already finished. Partial image b) shows the corresponding curve variation when at least one of the tires is a new tire with circumferential growth. The speed axis V is subdivided into speed intervals V0 to V7. Initially, the pressure loss detection method mentioned hereinabove records in the intervals individually during a learning phase the usual running characteristics of the vehicle wheels in different driving situations. When the learning phase is terminated, the comparison phase with the actual pressure loss detection is activated. The reset tip switch is pushed at time t0. A new tire is suspected at t1. DDS is disabled. At t2, after a reasonable waiting time in the range of 10 to 15 minutes approximately, there is certainty that tire growth in this speed range and in the underlying speed ranges is

finished. Subsequently, DDS is reset completely so that the learning phase with the subsequent comparison phase is active again. Only with a repeated detection of a new tire (interval V6 at t3) will DDS be disabled again, and the detection of new tires is performed as described hereinabove.

Figure 3 shows the mode of function of the algorithm for the new tire detection in a DDS system in detail. The variable v_int indicates the instantaneous speed interval. To simplify the problem, it can be assumed for the detection that the new tire growth being detected will not occur before the first learned value was determined.

Figure 4 explains the mode of function of the new tire detection in detail. The growth of the tire circumference is written down individually for various speed intervals. The learned value for the instantaneous speed interval is compared with the value of the preferably averaged or filtered reference value Ref (Y-axis in partial image a)) according to the method. The number n of the data record (samples), which has been considered in the determination of reference values in the respective speed interval, is plotted on the x-axis. Curve 402 shows the variation of Ref during tire growth. Curve 403 shows the variation when tire growth is lacking. For the detection of tire growth in the instantaneous V-interval, a counter Z (Y-axis in the partial image b)) is used in each V-interval which is counted upwards when the value Ref is higher than the constant A. Counter Z is counted downwards when the value Ref is lower than a constant -A. Curve 404 indicates the count of Z during tire growth, while curve 405 relates to the example without tire growth. Number 401 designates the point of time commencing which the counter is counted upwards. When the counter, as illustrated in partial image b), reaches a top

or bottom limit value (constant B), the flag 'growth detected' is set, whereby the algorithm is notified of a detection of tire growth.

When the vehicle has been driven in a V-interval (V_i) for a defined time, the algorithm assumes that the new tire growth is finished. Upon expiry of the predefined time, the flag 'growth finished in speed interval V' is set for this purpose.

<u>Distinction between growth and pressure loss</u>

According to the method of the invention a distinction can be made between a pressure loss and remaining tire growth in the following cases:

Case 1: The effect on Ref(t) as a result of pressure loss causes a high gradient and a high absolute amount compared to the remaining tire growth.

Case 2: Wheel detection according to the method described hereinbelow is possible.

Case 1, for example, concerns pressure loss during vehicle standstill after a learning operation in this speed interval or a very quick pressure loss. It is especially preferred that the count of the counter Z is once more counted downwards when the value of Ref reaches a second limit value (constant C). This protects the system against indicating growth of a new tire, although actually pressure loss prevails.

The following physical relationship is assumed in case 2: Pressure losses at a wheel cause a smaller dynamic tire circumference and, hence, the detection of a faster rotating

wheel. In contrast thereto, continuing tire growth would lead to a reduced rotational speed of the wheel. Growth in the case of detection of a fast wheel can be ruled out this way. In the last-mentioned case the counter for the pressure detection ZP is counted upwards by the value 1.

Consequences of growth detection

When new tire growth was detected in a V-interval, the flag 'growth detected' is set. In consequence of this, the counter ZP provided for pressure loss detection will not be counted further. Pressure loss warning is omitted because it is not activated until ZP has exceeded a predetermined count of the counter. When in addition growth no longer takes place in the current V-interval, the system is reset (Reset) so that the learning phase re-commences in all V-intervals. The information about the termination of the growth of the new tire in the respective V-interval is, however, stored by means of the system.

Avoiding faulty new tire detection

The function 'recheck growth' (301 in Figure 3) is used as a protection against a faulty new tire detection, it checks at low speeds e.g. below 100 k.p.h. In these low V-intervals, tire growth can no longer occur at least in those cases when tire growth has occurred already in a higher speed interval.

This is based on the following findings: When in the low speed interval the values Ref are close to the corresponding learned values and it was simultaneously detected that driving took place in a high speed interval, then tire growth cannot remain from driving in the high speed interval.

Avoiding an incorrect recheck

The function 'recheck growth' can also be incorrect when a V-interval for the recheck was not learned before the recheck function became active. A possible way out involves storing the status information about the learning operation at the time when the flag 'growth detected' is set. The recheck function can just have been activated when the second warning threshold in a low V-interval was learned for which the recheck function is provided. It should be noted that working with the first threshold values can lead to errors being caused by continued learning or restarted learning in the event of incorrect learning detection.

The information about the learning status at the moment of growth detection is stored in a variable or memory location provided for this purpose.

Resetting (Reset) and initialization

The system can be fully reset when a Reset was detected by the driver or by a diagnosis function. The flags for detecting the new tire growth are not reset in the event of an internal DDS reset being possibly performed for any other reason.

According to a second embodiment, which can be used alternatively or in conjunction with the first embodiment, the DDS pressure loss detection method described hereinabove initially determines in a per se known manner three differently determined reference values, Ref_{diag} (Figure 6, reference numeral 6) for the relations of diagonals, Ref_{side} for the relations of sides, and Ref_{axle} for the relations of axles.

After termination of a learning phase, learned values prevail for each of these reference values, by way of which pressure loss can be detected in a per se known manner by a comparison with currently determined reference values. Restart of the learning phase normally starts with the driver actuating a reset tip switch after a tire filling operation or after replacement of the tires or wheels.

It is preferably provided in addition that after response of the method for new tire detection, which triggers e.g. a restart of DDS, the detection is not activated a second time. It is thus prevented that the system constantly 'learns after' the current reference values with multiple DDS-Resets. Pressure loss detection that is appropriately sensitive would no longer be safeguarded in this case. More particularly, a new detection is possible again only when a signal has been generated for a DDS-Reset, for example after new tires have been mounted.

The expansion effect of a new tire described hereinabove can disturb the above pressure loss detection. Therefore, the corresponding effects of a new tire are taken into consideration in the following way.

Figure 6 is a diagrammatic view of the mode of function of the new tire detection. The function module 'DDS' (not shown) provides three differently determined reference values 4, 5, 6. According to the method, the difference between an acquired learned value and a currently determined (filtered) reference value is examined. When a tire grows, the corresponding wheel will rotate more slowly. This leads to a change of the reference value for the relation of diagonals, sides and axles. The change of the three values can be distinguished

from the change during pressure loss. In function group 1 it is found out with the aid of further differently determined reference values, which wheel exhibits a new tire effect. This information is submitted by way of signal path 3 to a probability-monitoring device 2. When the change (difference between the respective Ref-value and the associated learned value) exceeds a first threshold that is lower than the DDS-threshold for pressure loss detection, tire growth is suspected. The probability that tire growth exists increases by further successively determined reference values when a current reference value likewise fulfils the above criteria. The probability is implemented by way of a simple counter in function module 2. When this counter exceeds a predefined threshold value, new tire growth is very likely to prevail. In this case, Reset-signals are sent to the module 'DDS' through lines 8, 9, 10. Line 7 temporarily disables the DDS function.

According to a preferred embodiment of the method, the reference value for the relation of diagonals is additionally processed by way of signal line 11. The threshold values for the evaluation of the relation of diagonals are set to be higher in comparison with the remaining reference values in the processing operation. It is this way possible to still further enhance the detection reliability of the new tire detection.

Line 12 transmits a quantity about the quality of the roadway condition and the signal quality determined by means of the function module 'DDS'. If the quality of the roadway or the signals is poor, the increase of the count of the counter is preferably suppressed when new tire growth is suspected.

Signal line 13 is provided to limit the detection of growth of a new tire to defined pre-selected kilometer readings. This function is based on the idea that starting with a defined kilometer reading that is to be fixed in an appropriate manner, new tire growth is no longer allowed to occur. It is preferred that the kilometer reading is related to the last DDS-Reset in order that a changing of tire will not be neglected by the system.

The method of the detection of growth of a new tire as described hereinabove can also be implemented separately for individual speed intervals. When, for example, the vehicle has been driven in a corresponding speed interval for a defined time, the algorithm assumes that the new tire growth is terminated only for this interval. Accordingly, it is also possible to learn and evaluate the reference values for different speed intervals independently of each other when a sufficient size of memory location is available.

A distinction between tire growth and pressure loss can also favorably be made in that a top threshold value is defined that cannot be exceeded by the influence of tire growth on the change of a reference value.

Further possibilities of distinguishing between tire growth and pressure loss:
The effect on a reference value as a consequence of pressure loss has a high gradient.

It is particularly preferred that the probability counter is counted downwards when the value of Ref reaches or exceeds the second limit value. This saves the system from indicating new tire growth when actually pressure loss prevails.